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ter. Doubtless then the Rust of Maize is carried over from year to year in part by means of surviving uredospores. Finally, it may be said that while this interpretation was, of course, not unthought of by uredinists, I preferred myself to record the final judgment only after further work had been carried on in my own experimental laboratory. Therefore this is the conclusion of the whole matter.

CULTURES OF UREDINEAE IN 1905.[1]

BY J. C. ARTHUR.

The present article forms the sixth of a series of reports[2] by the author upon the culture of plant rusts. They cover the years from 1899 to the present year, inclusive. In these studies the grass and sedge rusts hold a prominent place, but other heteroecious and autoecious species have been included, and during the present season the work has been extended to the so-called *opis, micro* and *lepto* forms, and also to species with amphispores.

The coöperative agreement between the Bureau of Plant Industry of the U. S. Department of Agriculture and the Indiana Experiment Station, which existed for carrying on the culture work in the spring of 1904, was again established, extending from July, 1904, to April 30, 1905, making it possible to have an assistant during this period, who devoted nearly his whole time to the study of the rusts. The position was first held by Mr. J. C. Marquis, who was succeeded on October 1, 1905, by Mr. Frank D. Kern, and after the expiration of the coöperative agreement Mr. Kern was retained by the Experiment Station to continue the work. After May 10 all the work fell upon Mr. Kern until September, covering the most important part of the culture period, the author being absent in Europe. It could not, however, have been entrusted to better hands, as the fine ability displayed in the work during the previous season, coupled with considerable experience already acquired, enabled him to meet the new conditions as they arose, and the judgment and caution indispensable in securing authoritative results.

Much of the completeness of the work is due to the kindly assistance of correspondents, who have sent teleutosporic material, and especially to Messrs. E. Bethel, Denver, Colo.; J. M. Bates, Red Cloud, Neb.; A. O. Garrett, Salt Lake City, Utah;

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[1] Read before the Botanical Society of America at the New Orleans meeting, January 1, 1906.

[2] See Bot. Gaz. *29*: 268-276; Jour. Mycol. *8*: 51-56; Bot. Gaz. *35*: 10-23; Jour. Mycol. *10*: 8-21 and *11*: 50-67.

J. J. Davis, Racine, Wis.; E. Bartholomew, Rockport, Kansas; H. H. Whetzel and H. S. Jackson, Ithaca, N. Y.; C. L. Shear and P. L. Ricker, Washington, D. C.; Wm. J. Horne, Santiago de las Vegas, Cuba; Jos. J. Wolfe, Durham, N. C.; Lewis Kaufman, Morrison, Iowa; R. D. Echlin, Washington, Iowa'; R. E. Buchanan, Ames, Iowa; H. L. Bolley, Fargo, N. D.; and H. L. Shantz, Lincoln, Neb.; to whom my warmest thanks are extended. I am also much indebted to Messrs. Bethel and Garrett for rooted wild plants on which to make sowings, and to Dr. Davis for field observations and the suggestion which led to successful sowings of *Puccinia Eleocharidis.*

During the present season 85 collections of material with resting spores and 15 collections with active spores were employed, from which 484 drop cultures and 13 Petri dish cultures were made to test the germinating condition of the spores, these being made almost wholly from the resting spores. Out of the 85 collections with resting spores 32 could not be made to germinate, although every condition seemed favorable, and were therefore useless. There were in all 194 sowings of spores made, representing 45 species of rusts, and for this purpose 100 species of hosts were utilized, which were grown temporarily in pots in the greenhouse.

A few cultures were made with heteroecious species for which no clue to the alternate host had been obtained, and with one exception the results were negative. These negative trials are here recorded to serve for reference.

1. PUCCINIA on *Carex Pennsylvanica,* sent by Rev. J. M. Bates from Red Cloud, Neb., was sown on *Urtica gracilis* with no infection. Similar material in former seasons has been tried on twenty-one other species of hosts with negative results.[3]

2. PUCCINIA EMACULATA Schw. on *Panicum capillare* L. from Lafayette, Ind., was sown on *Ambrosia artemisiaefolia, Rudbeckia triloba, R. laciniata* and *Steironema ciliatum,* with no infection. This very common and distinctive rust was sown in former seasons on fourteen other species of hosts with negative results.[4]

3. PUCCINIA TOSTA Arth., on *Sporobolus asperifolius,* sent from Denver, Colo., by Mr. E. Bethel, was sown on *Napaea dioica Symphoricarpos racemosus, Xanthoxylum Americanum, Aesculus glabra* and *Viola papilionacea,* with no infection. Sowings of what is taken to be the same species of rust, but on

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[3] See Jour. Mycol. *10*: 10. 1904; and *11*: 51. 1905.

[4] See Jour. Mycol. *8*: 52. 1902; Bot. Gaz. *35*: 12. 1903; and Jour. Mycol. *10*: 10. 1904.

another host, were made in 1903 on six other species of hosts with negative results.[5]

4. PUCCINIA CRANDALLII Pamm. & Hume, on *Festuca confinis*, sent from Boulder, Colo., by Mr. E. Bethel, was sown on *Dodecatheon Meadia, Hydrophyllum appendiculatum, Aquilegia Canadensis, Anemone Canadensis, Thalictrum dioicum, Rudbeckia triloba, Gutierrezia Sarothrae,* and *Lonicera Japonica*, with no infection.

5. UROMYCES GRAMINICOLA Burr. on *Panicum virgatum*, sent from Red Cloud, Neb., by Rev. Bates, was sown on *Psoralea Onobrychis*, with no infection; while similar material sent by Mr. Bartholomew from Stockton, Kans., was sown on the same host and also on *Cassia Chamaecrista, Polemonium reptans* and *Rudbeckia laciniata*, all with no infection.

6. UROMYCES JUNCI (Schw.) Tul. on *Juncus effusus*, sent by Mr. Jackson from Ithaca, N. Y., was sown on *Rudbeckia laciniata, R. triloba,* and *Falcata comosa*, with no infection. What is believed to be the same species of rust, but on another host, was sown in 1902 on a species of *Iris* with negative results.

The following species of rusts were successfully grown, and the data supplement that obtained from previous cultures of this series, or that published by other investigators obtained by means of similar cultures. The results in connection with *Puccinia Pruni-spinosae*, the plum rust, are especially interesting, being the first studies of the kind with American material.

1. MELAMPSORA MEDUSAE Thuem.— Teleutosporic material obtained near Lafayette, Ind., on *Populus deltoides* was sown April 17 on *Larix laricina* and *L. decidua*, which resulted in abundance of spermogonia appearing April 25, and a greater abundance of aecidia May 1, upon both hosts.[6]

2. GYMNOSPORANGIUM JUNIPERI-VIRGINIANAE Schw.— Three samples of teleutosporic material were used, one from the eastern states, and two from the central west. The test was designed to show whether any difference existed between the two regions in the power of the species to infect the cultivated apple; the apple orchards of Iowa and the central west generally being well known to be especially free from this rust. All the teleutosporic material was on *Juniperus Virginiana*, and to all appearances equally good. That sent from Durham, N. C., by Mr. Wolfe, was sown on a seedling apple out of doors April 27, and showed abundant spermogonia May 9, but did not develop

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[5] See Jour. Myc. *10*: 10. 1904.

[6] See Jour. Mycol. *10*: 13. 1904; and *11*: 52. 1905.

aecidia, although conditions appeared favorable. Material from Washington, Iowa, sent by Rev. Echlin, was sown April 22, on a small plant of the York Imperial apple in the greenhouse, and showed abundant spermogonia on May 5; another sowing was made out of doors on a seedling apple April 27, and showed spermogonia on May 13, but further observation was prevented by insect depredation. A second lot of material was received from Ames, Iowa, sent by Mr. Buchanan, and was sown out of doors on seedling apple and *Crataegus coccinea*, and in the greenhouse on *Amelanchier Botryapium*. The sowing on apple gave abundant spermogonia, but failed to make further development, while on the other hosts there was no infection. So far as these tests go there appears to be no difference between the eastern and western forms of the species in their power to infect the cultivated apple. Many cultures have been made showing the full life cycle of this rust (often called *G. macropus*). A good summary of the subject, especially in reference to the question underlying the present work, was given a short time ago by Professor Pammel[7] of the Iowa State College.

3. PUCCINIA SAMBUCI (Schw.) Arth. — Teleutosporic material of fine quality on *Carex lupulina*, collected in Noble county, near Beavor Dam, Ind., was sent by Mr. Whetzel. It was sown on *Sambucus Canadensis* May 8, giving rise to abundant spermogonia May 14, and aecidia May 25.

4. PUCCINIA ALBIPERIDIA Arth. — Teleutosporic material was gathered near Lafayette, Ind., on *Carex tetanica*, and sown April 7 on *Silphium perfoliatum, Polemonium reptans, Ambrosia trifida, Rudbeckia laciniata, Steironema ciliatum*, and *Ribes gracile*. Only the last host showed infection, giving abundant spermogonia April 14, and aecidia April 27, the others remained entirely free from rust.

A part of the teleutosporic material was sent to Dr. H. Klebahn, Hamburg, Germany, who sowed it on *Ribes Uva-crispa, R. aureum* and *R. rubrum*. No infection resulted on *R. rubrum*, but on *R. Uva-crispa* spermogonia showed May 8, and on *R. aureum* May 15. The further development, however, was slow, soon coming to naught in the first case, and persisting much longer, but with little advance in the second case. Dr. Klebahn in commenting upon his results says that the imperfect development of the infection on *R. uva-crispa* may be ascribed, in part at least, to the late sowing, for the teleutospores germinated freely. The host plants had already passed the most active period of growth, and the weather was too warm. His results are exactly in accord with our own under similar conditions. The failure to secure good aecidia made it impossible to give an opinion on the identity of this species of rust,[8] as compared with European forms.

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[7] Bull. Iowa Exper. Sta., No. 84: 16–24. August, 1905.

5. PUCCINIA CARICIS-SOLIDAGINIS Arth. — Teleutospores on *Carex sparganioides* gathered near Lafayette, Ind., were sown April 22 on *Aster paniculatus* and again on May 11 on *A. paniculatus, A. Drummondii, Ribes rotundifolium, Urtica gracilis,* and *Solidago Canadensis.* No infection occurred except on the last host, this giving spermogonia May 18 and aecidia May 28 in very great abundance. In 1902 cultures of this species were made with teleutospores taken from *Carex Jamesii* and *C. stipata.*[9]

6. PUCCINIA PECKII (DeT.) Kellerm. — Teleutosporic material on *Carex lanuginosa,* gathered at Red Cloud, Neb., by Rev. Bates, was sown May 19 on *Hydrophyllum appendiculatum, Steironema ciliatum,* and *Onagra biennis.* On May 26 spermogonia, and May 31 aecidia appeared on *O. biennis,* the other hosts remaining entirely unaffected. This result is a duplicate of that obtained in 1904.[10].

7. PUCCINIA CARICIS (Schum.) Reb. — Teleutosporic material on *Carex stipata,* gathered near Lafayette, Ind., was sown April 18 on *Urtica gracilis,* and gave spermogonia April 24, and aecidia May 1, in great abundance.

A collection in excellent condition made at Denver, Colo., by Mr. Bethel, on *Carex aquatilis,* was sown on *Urtica gracilis* April 10, giving few but well developed spermogonia April 18, and numerous aecidia April 29. It was sown again April 25, and gave abundant spermogonia May 1, followed with very numerous aecidia May 8.

Both of these sowings were tried on the evidence of the microscopic examination of the collections. It was found that the medium-sized teleutospores, and large uredospores found intermixed, agreed with those known to belong to this species, and the results confirmed the diagnosis. Both collections give new hosts for the species.[11] More interesting still was the presence in the Colorado collection of abundant amphispores, which agree in every particular with those collected on *Carex stricta* by C. H. Peck in New York, distributed in Thuemen's *Myc. Univ., No. 746,* and first called *Uromyces Caricis* Pk., then *Puccinia Caricis-strictae* Diet. This fortunate collection enables us to show beyond a reasonable doubt, that the *Uromyces Caricis* of Peck is the amphisporic form of *Puccinia Caricis.* What determines the production of amphispores in this species is an interesting question, in view of the fact that only twice have they been found, and at such a great distance apart. The amphispores in the Colorado collection did not germinate in drop culture, although the same conditions gave fine germination of the associated teleutospores.

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[8] For record of previous cultures see Jour. Myc. *8*: 53. 1902; *10*: 11. 1904; and *11*: 58. 1905.

[9] See Bot. Gaz. *35*: 21. 1903.

[10] Jour. Mycol. *11*: 58. 1905.

[11] For previous cultures see Bot. Gaz. *29*: 279. 1900; *35*: 16. 1903; and Jour. Mycol. *8*: 52. 1902.

8. PUCCINIA FRAXINATA (Schw.) Arth. — A collection of teleutospores on *Spartina cynosuroides,* sent by Mr. Bartholomew from Hill City, Kans., was used to sow April 29, on *Fraxinus lanceolata, Adelia acuminata* and *Ligustrum vulgare.* Only the first host gave results, showing spermogonia May 5, and aecidia May 14, the sowing being made on a cut branch placed in water in the greenhouse.[12]

9. PUCCINIA AMPHIGENA Diet. — Teleutosporic material on *Calamovilfa longifolia* sent by Rev. Bates from Red Cloud, Neb., was sown on *Smilax hispida* May 27, and began to show spermogonia June 2, and aecidia June 10, both in abundance.[13]

10. PUCCINIA VERBENICOLA (E. & K.) Arth. — Teleutosporic material on *Sporobolus longifolius,* sent from Red Cloud, Neb., by Rev. Bates, was sown on *Verbena urticaefolia* May 3, and showed spermogonia May 9, and aecidia May 20. Another collection on same host, obtained near Lafayette, Ind., was sown on same species of *Verbena* May 27, and showed spermogonia June 2, and aecidia June 10.[14]

11. PUCCINIA PUSTULATA (Curt.) Arth. — Teleutosporic material on *Andropogon furcatus,* gathered by the writer at English Lake, Ind., was sown on *Pentstemon hirsutus* and *Comandra umbellata* May 27, with no infection of the *Pentstemon,* but abundant growth on the *Comandra,* spermogonia appearing June 2, and aecidia June 14. This result confirms work done in 1903.[15]

12. PUCCINIA PAMMELII (Trel.) Arth. — The cultural results of 1904[16] were verified by sowing teleutospores from *Panicum virgatum,* obtained by the writer at English Lake, Ind., upon*Euphorbia corollata.* A sowing was made May 26, giving spermogonia June 2, and aecidia June 9.

13. PUCCINIA SUBNITENS Diet. Teleutosporic material on *Distichlis spicata,* sent from Red Cloud, Neb., by Rev. Bates, was

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[12] For previous cultures see Bot. Gaz. *29*: 275. 1900; and Jour. Mycol. *11*: 57. 1905.

[13] For previous cultures see Bot. Gaz. *35*: 20. 1903; and Jour Mycol. *10*: 11. 1904.

[14] For previous cultures see Bot. Gaz. *29*: 274. 1900; *35*: 16. 1903; and Jour Mycol. *11*: 56. 1905.

[15] Jour. Mycol. *10*: 17. 1904.

[16] Jour. Mycol. *11*: 56. 1905.

sown on *Erysimum asperum, Sophia incisia,*[17] *Lepidium Virginicum,* and *Bursa Bursa-pastoris,* with success in each case. The sowing was made April 18, and spermogonia appeared on *Eryisimum* and *Sophia* April 25, *Lepidium* April 26, and *Bursa* April 27, while aecidia were observed on all by May 8. The aecidia develop with considerable difficulty on *Bursa,* and Rev. Bates writes that they are not common or abundant in the field on this host. On *Lepidium* they also start with less ease than on the other species, but under good conditions grow well.[18]

14. Puccinia poculiformis (Jacq.) Wettst. — Teleutosporic material on *Agrostis alba,* sent from Ithaca, N. Y., by Mr. Jackson, was sown on *Berberis vulgaris* April 13, and showed numerous spermogonia April 22, with abundance of aecidia May 4.

15. Puccinia Sorghi Schw. — The work of last year,[19] in which only aecidia were used, was verified this season by sowing teleutospores. The material was obtained in Lafayette from an early garden variety of sweet corn. It was sown April 17 on *Oxalis cymosa* (the common wild wood sorrel of the region), *O. Ortgiesii* (a yellow-flowered greenhouse weed), *O.*———, (a tuberous pink-flowered form of greenhouses), and *O. Bowiei* (a pink-flowered form with large flowers and leaves, also grown in greenhouses.) All remained free, except *O. cymosa,* which showed numerous spermogonia on April 27, and aecidia on May 5. A second sowing was made May 1 on *O. cymosa, O. Origiesii, O. Bowiei, and O. corniculata* (growing out of doors over a grass-covered conduit for steam pipes), and again all remained free except *O. cymosa,* which gave spermogonia May 8, and eacidia May 14. It is not apparent why no infection should occur on the four hosts other than *O. cymosa,* but there is no reason to suppose that it was due in any degree to lack of vigor or suitable conditions.

The aecidiospores raised in the first trial above were sown May 6 on seedlings of the yellow dent field corn variety of *Zea Mays,* and in a week, May 13, showed uredospores, which increased in abundance until teleutospores were observed June 15. The uredospores from this culture (on yellow dent corn) were sown May 16 on small plants of garden sweet corn, and gave uredospores in plenty on May 23, and would doubtless have been followed by teleutospores in due time, had the culture been continued. These results in transferring the rust from field corn to sweet corn, and the reverse, are in accord with those obtained by Kellerman.[20]

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[17] This is probably not the correct name of the plant used for the cultures. It is, however, the name also used last year for the trial host, which is the common species of *Sophia* in this region, and the error in determination is due to the confusion existing in the current manuals. The species is also different from the one on which the fungus was collected last year in Nebraska by Rev. Bates (Jour. Mycol. *11*: 116. 1905), and that is also incorrectly named. But for the sake of simplicity the name *S. incisa* will be used in this article for both species.

[18] For previous cultures see Bot. Gaz. *35*: 19. 1903; and Jour. Mycol. *11*: 54. 1905.

[19] Bot. Gaz. *38*: 64. 1904.

At the same time the first sowings were made, April 17, teleutospores were also sown on a seedling *Zea Mays*, under favorable conditions, but no infection resulted. The drop cultures, which are made just previous to every sowing, showed that the teleutospores germinated freely, but the few uredospores intermixed were not viable. In this case, at least, the teleutospores appeared to be incapable of infecting the host from which taken, and in so far agree with the general rule regarding grass and sedge rusts.

16. PUCCINIA POLYGONI-AMPHIBII Pers. — In 1904[21] it was possible to verify in a measure the work upon this species by Dr. Tranzschel of St. Petersburg, by sowing aecidiospores from*Geranium maculatum* and obtaining teleutospores on *Polygonum emersum*. This season the reverse order of sowing was tried. Teleutospores from *P. emersum* obtained in this vicinity were sown April 15 on *G. maculatum* and *G. Robertianum*, with no infection of the latter, but most abundant infection of the former, showing spermogonia April 23 and aecidia May 1. A second sowing was made April 27, using the above two hosts and also *G. pusillum*, and again infection occurred only upon *G. maculatum*, which showed great numbers of spermogonia May 3, and aecidia May 9. These results agree with common observation, for the aecidium on *G. maculatum* (*A. sanguinolentum* Lindr.) is common in the United States, while no aecidia have yet been reported on *G. Robertianum* or *G. pussillum*.

17. PUCCINIA HELIANTHI Schw. — A sowing of teleutospores, taken from *Helianthus grosse-serratus* growing on the grounds of the University, was made May 17 on *H. grosse-serratus* and two plants of *H. annuus* with equally abundant results in each case, spermogonia showing May 25, and aecidia June 2.

18. PUCCINIA LATERIPES B. & Br. — After many vain attempts to secure good fungous and host material of this species for culture work, the present season's excellent results have given much satisfaction. All the material was obtained near Lafayette, Ind. Sowings of teleutospores from *Ruellia ciliosa* were made April 25 on both *R. ciliosa* and *R. strepens*, with equally positive results in both cases, showing spermogonia May 5, and aecidia May 18. Another sowing of the same material was made on *R. strepens* May 27, which gave spermogonia June 5, and aecidia

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[20] Cf. Jour. Mycol. *11*: 27. 1905.

[21] Jour. Mycol. *11*: 59. 1905.

June 15. A sowing of teleutospores from *R. strepens* on *R. ciliosa* May 8, and another June 7, gave no infection.

Many writers, following Lagerheim, who received his clue from Burrill, have made two species of the rusts on these two hosts. It is true that the gross appearance, and to some extent the microscopic characters of the two are perceptibly different. These differences are shown, so far as the development went, in the results of the cultures. The aecidial groups grown on *R. ciliosa* were small and round, one to two millimeters across, without noticeable hypertrophy of the tissues, and confined to the blade of the leaf. On *R. strepens,* however, they took possession of the veins, petioles and stems, and made large swellings from 20 to 25 millimeters long, and in one case the main steam for a distance of ten centimeters or more was greatly swollen and distorted. The differences also extended to the peridial cups and to the spores. On *R. ciliosa* the cups were mostly one-half millimeter high, and on *R. strepens* fully one millimeter high. The aecidiospores from *R. ciliosa* measured 15-19 by 20-26μ, and from *R. strepens* 17-21 by 24-30μ. These two cultures were from the same source of infection, and must therefore be one and the same species. Had uredospores and teleutospores been raised, it is believed that the differences recorded in the books for the two hosts would have been found. In short it is believed that the differences of size and appearance are entirely due to the influence of the hosts. The loose, somewhat succulent tissues of *R. strepens,* and its vigorous habit of growth, are correlated with the greater development of the fungus, while the firm close tissues of *R. ciliosa,* not only prevent luxuriant development of the parasite, but its parts become smaller throughout. These differences in the hosts also account for the failure to infect *R. ciliosa* with spores from *R. strepens,* while the reverse process succeeded. There appears to be no reason to doubt that under very favorable conditions the infection of *R. ciliosa* with spores from *R. strepens* could be accomplished, and the resulting development be the same as when the infecting spores came from *R. ciliosa* itself.[22]

19. PUCCINIA PRUNI-SPINOSAE Pers.— The *Aecidium punctatum* Pers. (*A. quadrifidum* DC.) occurring in various parts of the United States and Canada on different species of *Anemone, Hepatica* and *Thalictrum* so closely resembles the European form which bears the same name, that little doubt has existed of their genuine identity. In 1904 Dr. Tranzschel[23] of St. Petersburg made cultures of this aecidium, sowing the aecidiospores from *Anemone coronaria* on *Amygdalus communis* (almond) *Prunus spinosa* (blackthorn), *P. divaricata* (cherry-

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[22] For previous cultures see Kellerman in Jour. Mycol. *9*: 107. 1903.

[23] Trav. Mus. Bot. Acad. Sci. St. Petersb. *11*: 67-69. 1905.

plum) and from *Anemone ranunculoides* on *P. spinosa,* producing in each the characteristic uredospores of *Puccinia Pruni-spinosae,* the rust of plums and peaches.

This work by Dr. Tranzschel suggested the following trials with American material. Aecidiospores from *Hepatica acutiloba* (*Aecidium hepticatum* Schw.) were sown on three small plants of *Prunus serotina* (wild black cherry), established in pots in the greenhouse, on *Prunus Americana* (native plum), *P. Cerasus* (cultivated cherry), and *Amygdalus Persica* (peach), the last two seedlings. The sowings were made May 1 to 4, and in fifteen days afterward, uredospores appeared on *P. serotina,* but the other plants remained wholly free, watch being continued for a month and more. The successful sowings were as follows:

May 1, Aecidiospores sown on *P. serotina;* May 16, uredospores; May 22, teleutospores.
May 1, Aecidiospores sown on *P. serotina;* May 16, uredospores.
May 2, Aecidiospores sown on *P. serotina;* May 17, uredospores.

On May 23, a sowing of uredospores, which had been grown on *P. serotina,* was made on *A. Persica,* under seemingly most favorable conditions, but no infection took place, watch being kept for two months.

From these results there can be no further question of the general identity of the American and European plum and cherry rusts, and their connection with the *Aecidium punctatum.* It is not possible to state what significance is to be attached to the failure to infect peach, plum and cultivated cherry with spores that readily infected the wild cherry. Careful search for two seasons in the vicinity of the diseased hepaticas, the fungus being perennial, has failed to detect any rust on plums, cherries or peaches, wild or cultivated, although growing in plenty; and furthermore *Puccinia Pruni-spinosae* has not yet been reported from Indiana, although said to occur in the adjoining state of Illinois on *P. serotina, P. Virginiana,* and *P. Americana.*

20. PUCCINIA XANTHII Schw. — Teleutosporic material on *Xanthium Canadense,* gathered near Lafayette, Ind., on Nov. 5, 1904, was sown on the second and third leaves of seedlings of the same species of host April 3. On April 8 small yellow dots began to show, which closely simulated spermogonia, but which microscopic examination by means of sections proved were only the very young teleutosporic sori. The yellow dots increased in size, appearing like small pimples, and finally broke through the epidermis, exposing the teleutospores April 21, eighteen days after inoculation. Another sowing was made April 13, on the cotyledons of the same species of host, and on the second leaves of *Ambrosia trifida.* The *Xanthium* seed-leaves showed yellow dots on April 22, and open sori May 1, also in eighteen days from sowing, but the *Ambrosia* leaves remained free.

These results agree essentially with those reported by Carleton,[24] who was able to infect *Xanthium* in eighteen and fourteen days, but could not infect *Ambrosia.* He says, however, that "in all these cases spermogonia preceded the teleutospores in the infected spots." In connection with an account of cultures with *Puccinia heterospora* he adds that "numerous experiments were also made with other *lepto* species, including *Puccinia Grindeliae* Pk., *P. variolans* Hark., *P. Lygodesmiae* E. & E., and *P. Sherardiana* Korn., with results similar to those above mentioned," but he does not report the details of these cultures, if such they were.

Taking the observations here recorded for *P. Xanthii,* especially in connection with those for *P. Silphii* and *P. Grindeliae,* reported below, it seems safe to assume that these species, and those quoted as mentioned by Carleton, belong to a group of rusts in which teleutospores and their resulting sporidia are the only spore-forms produced in the life-cycle, aecidia, uredo, and even spermogonia being wholly absent.

The following nine species have never been tested before by the culture method, so far as the writer knows, either in this country or abroad. They embrace an interesting diversity of habit. Besides the grass and sedge forms, with which this series of cultures has been most concerned, there are two leptopucciniae, one micropuccinia and one brachypuccinia, also one of the grass rusts is chiefly interesting for its amphispores.

1. Puccinia Silphii Schw. — Teleutosporic material was gathered March 31, 1905, near Lafayette, Ind., on dead and weathered leaves of *Silphium integrifolium,* and sown April 10 on vigorous plants of the same host, and also on *S. perfoliatum.* There was no infection on the latter host, but on the former clear yellow dots showed April 15, which sectioned and placed under the microscope proved to be very young teleutosori. These yellow dots rapidly enlarged, forming pale pimples scattered over yellow patches of the leaf, with much hypertrophied tissues, and April 20 broke through the epidermis, exposing the abundant teleutospores. Another sowing on the same two hosts was made April 25, and with the same results: there was no infection of *S. perfoliatum,* and the most abundant infection of *S. integrifolium,* showing as yellow dots May 2, and exposed teleutospores May 5. As the rust occurs on both these species of *Silphium,* and many others as well, the results may be taken as indicative of biological races.

2. Puccinia Grindeliae Pk. — Excellent teleutosporic material on *Gutierrezia Sarothrae* was sent by Mr. Bethel, collected

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[24] Bulletin Bureau Pl. Industry, No. 63: 26. 1904.

at Boulder, Colo., March 27, 1905, on weathered stems. Mr. Bethel also kindly sent growing plants of the host and of *Chrysothamnus nauseolus.* The latter is not a recorded host for *P. Grindeliae,* but for a similar species, *P. tuberculans* E. & E. A sowing was made on *G. Sarothrae* April 12, which showed yellow dots April 21, and numerous open teleutosori May 2. Another sowing was made on both hosts April 26, with no infection on *C. nauseolus,* but most abundant infection on *G. Sarothrae,* showing yellow dots May 4, and open teleutosori May 15. The yellow dots were investigated, as in the other instances, and found to be the early stages of teleutosori, with no trace of spermogonia.

3. PUCCINIA SOLIDAGINIS Pk. — Teleutosporic material was sent by Mr. Garrett, collected at Salt Lake City, Utah, on *Solidago trinervata,* April 8, 1905. It was sown on *S. Canadensis* May 17, showing yellow dots June 2, and an abundance of open teleutosori June 7, with considerable hypertrophy of the tissues. Although the yellow dots were not specially investigated, they gave the same appearance of being young sori, as in the above species of leptopucciniae.

4. PUCCINIA TRANSFORMANS E. & E.— Remarkably fine teleutosporic material, forming considerable excrescences on leaves and stems of *Stenolobium Stans* (*Tecoma Stans*), was sent by Mr. Horne, who collected it at Santiago de las Vegas, Cuba, May 3, 1905. It was sown on two young plants of *S. Stans* May 13, and in both cases gave abundance of spermogonia May 29, and of teleutospores June 5.

Fine material gathered by Mr. J. B. Rorer on the pods of *S. Stans* in the Bahama Ids., at Nassau, New Providence, March, 1904, was sent for identification. The pods contained many seeds, which were planted in the greenhouse, and provided the host plants for the above inoculations. The teleutospores of this collection were in good germinating condition. As there were no growing plants of *S. Stans* at hand, they were sown May 20 (1904) on vigorous young plants of *Campsis radicans* (*Tecoma radicans*), but gave no infection, although the conditions seemed particularly favorable.

Since the cultures were made a study of the characters of the species has been undertaken, and the conclusion reached that all North American collections, so far as known, belong to *P. transformans* (*P. exitiosa* Syd. & Holw.). An original specimen of *P. transformans,* collected in Baja California by K. Brandegee in 1893 *on Tecoma Stans,* has been examined, and found to agree with other specimens on the same host from the West Indies, and also with the type material of *P. exitiosa* on *Tecoma mollis,* that is *Stenolobium mollis,* from Mexico. The species possesses considerably smaller spores, with thinner walls and finer sculpturing, than *Puccinia elegans* Schröt., reported only from Argentine, South America, an original specimen of which I have been able to examine through the courtesy of Dr. P. Hennings of the Botanical Garden, Berlin. *P. transformans* has not yet been reported from any locality in the United States.

5. PUCCINIA KUHNIAE Schw. — Teleutosporic material, gathered near Lafayette, Ind., Nov. 3, 1904, on *Kuhnia eupatorioides,* was sown on the same host May 19. On May 28 spermogonia appeared sparingly, which were examined under the microscope in section, and these were followed June 5 by uredo in fair abundance. The species, therefore, belongs to the group of brachypuccinia.

6. PUCCINIA CANALICULATA (Schw.) Lagerh. — An observation in the field made in 1904 led to the present successful cultures. Aecidia were found in remarkable abundance on seedling *Xanthium Canadense* over an area 8 to 10 meters in diameter, beyond which the aecidium did not occur, although the hosts were equally plentiful and equally exposed. Later in the season, the middle of June, uredosori were found upon what appeared to be a seedling sedge extending over approximately the same area that had been occupied in the spring by the cocklebur cluster cups, and this was followed in August by teleutosori. Although the sedge did not fruit, yet it was not difficult to ascertain that it was a species of *Cyperus,* and the rust *Puccinia canaliculata.*

On May 11 a sowing of aecidiospores, obtained from the locality mentioned, was made in the greenhouse on *Cyperus esculentus,* other species of the genus not being at hand, and on June 2 uredo were noticed, although they probably appeared earlier and were overlooked, being small and pale. Another sowing was made on the same species of host May 17, and uredo first noticed June 2. The plants did not grow well, and the infected leaves were removed for the herbarium before time enough had elapsed in which to develop telutosori. Cultures with teleutosporic material will doubtless confirm this association of the *Xanthium* and *Cyperus* rusts.

7. PUCCINIA ELEOCHARDIS Arth.— Teleutosporic material on *Eleocharis palustris* was sent by Dr. Davis from Racine, Wis., and with it the information that from observations in the field he believed this to have its aecidial phase on *Eupatorium.* Acting upon this suggestion, a sowing was made May 5 on *Eupatorium perfoliatum,* which gave rise to spermogonia May 13, and aecidia May 22. Another sowing on the same species of host May 11, gave spermogonia May 20, and aecidia May 30. Both trials produced an abundance of aecidia, with all the characteristics of the common and widely distributed form on this host, and closely related species.

8. PUCCINIA SUBSTERILIS E. & E. — Fine material on *Stipa viridula* collected in August, 1904, at Boulder, Colo., was sent by Mr. Bethel, who also sent living plants of *S. viridula* and *S. comata.* This material showed a great abundance of amphispores,[25] but almost no teleutospores. The amphispores gave good germination, and were sown April 6 on *S. viridula* and *S. comata.* Uredospores of the usual kind began to appear on *S. viridula* April 18, but no infection on *S. comata.* Another sowing was made April 22 on *S. comata,* which also gave no infection. Uredospores continued to form for a month on *S. viridula,* but no amphispores or teleutospores were produced.

Mr. Bethel also sent fine teleutosporic material on *Stipa comata,* collected in March, 1905, at Boulder, Colo. This was sown on *Aster ericoides* April 18, and contrary to expectation gave no infection. When the failure became assured, it was sown again, April 29, on *A. ericoides, A. multiflorus,* and *A. Novae-Angliae,* but in each case without infection. This negative result throws some doubt on the assumption that the American *Stipa* rusts on the several species of hosts belong to one species, having its aecidia on certain species of *Aster,*[26] and the present very incomplete report is therefore entered under the name *P. substerilis.* Reducing this name to a synonym of *P. stipae,* as the writer did a few months since,[27] is now believed to have been premature.

9. PUCCINIA SEYMOURIANA Arth. — At the time this species was published,[28] it was suggested upon grounds of spore resemblance that its *Aecidium* was *A. Cephalanthi* Seym. From combined morphological and geographical data I was then willing to assert that "although cultures must be awaited, yet there can be little doubt that the early stages of *P. Seymouriana* occur upon *Cephalanthus.*" Persistent efforts to secure material for this trial were finally rewarded by the writer finding especially good teleutospores on *Spartina cynosuroides* at English Lake, Ind., in the northern part of the state, in March, 1905. These were sown on *Polygala Senega* April 20, with no infection, and later on *Cephalanthus occidentalis,* May 13, with abundant results. On May 18 great numbers of spermogonia began to show, and on May 27 still greater numbers of aecidia, thus verifying the prediction made three years before.

10. UROMYCES ACUMINATUS Arth. — Finding the aecidium of this very common rust was due to a fortunate accident. Of the many trials to find the connection between the two phases

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[25] For description and illustrations of the amphipores in this species see Bull Torr. Bot. Club *32*: 38. 1905.

[26] For cultures of *Puccinia Stipae* see Jour. Mycol. *11*: 63. 1905.

[27] Jour. Mycol. *11*: 11. 1905.

[28] Bot. Gaz. *34*: 12. 1902.

of a heteroecoius rust, during my seven years of experimental work, this is the first instance of success without the aid of some probable clue, and in this case may be ascribed to good luck and the exuberant enthusiasm of Mr. Kern, who made all the sowings of the season.

Teleutosporic material on *Spartina cynosuroides,* collected at Palmer, Neb., by Rev. Bates, was sown May 26, on whatever plants were available in the greenhouse, that are recorded as bearing aecidia of unknown teleutosporic connection. These hosts were: *Polemonium reptans, Polygala Senega, Cassia Chamaecrista, Psoralea Onobrychis, Rudbeckia laciniata, Ambrosia artemisiaefolia, Thalictrum dioicum, Viola papilionacea,* and *Steironema ciliatum.* To our great surprise *S. ciliatum* began to show spermogonia June 1, and abundant aecidia June 6, all others having no infection. Another sowing was at once made, June 2, which likewise gave spermogonia June 7, and aecidia June 12.

The aecidium on this host is recorded or known to the writer from Iowa, Illinois, Nebraska, Kansas, Wyoming and Minnesota. A collection made in Wisconsin [29] on *S. lanceolatum* is thought by Burrill[30] to be specifically distinct. Schlechtendahl's name, *Caeoma Lysimachiae,* sometimes used for American specimens, was founded on an aecidium on *L. thyrsiflora L.* (*Naumburgia thyrsiflora* (L.) Duby) from vicinity of Berlin, and doubtless is entirely distinct from American forms, with the possible exception of the reference in Farlow & Seymour's Host Index,[31] the basis for which is unknown to the writer. Schweinitz's name [32] *Aecidium Lysimachiae* applies to the form on *Lysimachia quadrifolia* and L. *terrestris,* only reported from North Carolina, and may well be considered distinct. What is now much needed is teleutosporic material from the Atlantic and Gulf coasts to be used in cultures for testing the above points, and in general the question whether the eastern and western forms are one species or not.

The great prevalence of this rust on *Spartina,* and the comparative rarity of the aecidia on *Steironema,* is doubtless due in part to the hardiness of the uredospores, which enable them to live over winter and start the uredostage in the spring under favorable conditions. This is the opinion expressed by Mr. Bartholomew in a recent interview, and is my own opinion, founded in part upon finding uredosori upon young blades of *Spartina* only a few inches long at such an early date in spring that infection by means of aecidiospores seemed highly improbable.

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[29] Trelease, Paras. Fung. Wis. p. 30.

[30] Burrill, Paras. Fung. Ill., I. Uredineae, p. 233.

[31] L. c. p.75. 1890.

[32] Schrift. d. nat. Ges. Leipzig *1*: 67. 1822.

SUMMARY.

The following is a complete list of successful cultures made during the season of 1904. It is divided into the two series: species previously reported by the writer or other investigators, and species now reported for the first time.

A. Species previously reported.

1. MELAMPSORA MEDUSAE Thuem. — Teleutospores from *Populus deltoides* Marsh. sown on *Larix laricina* (DuR.) Koch.

2. GYMNOSPORANGIUM JUNIPERI-VIRGINIANAE Schw.—Teleutospores from *Juniperus Virginiana* L. sown on *Malus Malus* (L.) Britt.

3. PUCCINIA SAMBUCI (Schw.) Arth. — Teleutospores from *Carex lupulina* Muhl. sown on *Sambucus Canadensis* L.

4. PUCCINIA ALBIPERIDIA Arth. — Teleutospores from *Carex tetanica* Schk. sown on *Ribes gracile* Michx.

5. PUCCINIA CARICIS-SOLIDAGINIS Arth. — Teleutospores from *Carex sparganioides* Muhl. sown on *Solidago Canadensis* L.

6. PUCCINIA PECKII (DeT.) Kellerm. — Teleutospores from *Carex lanuginosa* Michx. sown on *Onagra biennis* (L.) Scop.

7. PUCCINIA CARICIS (Schum.) Reb. — Teleutospores from *Carex stipata* Muhl. and *C. aquatilis* Wahl. sown on *Urtica gracilis* Ait.

8. PUCCINIA FRAXINATA (Schw) Arth. — Teleutospores from *Spartina cynosuroides* Willd. sown on *Fraxinus lanceolata* Borck.

9. PUCCINIA AMPHIGENA Diet. — Teleutospores from *Calamovilfa longifolia* (Hook.) Hack. sown on *Smilax hispida* Muhl.

10. PUCCINIA VERBENICOLA (E. & K.) Arth. — Teleutospores from *Sporobolus longifolius* (Torr.) Wood, sown on *Verbena urticaefolia* L.

11. PUCCINIA PUSTULATA (Curt.) Arth. — Teleutospores from *Andropogon furcatus* Muhl. sown on *Comandra umbellata* (L.) Nutt.

12. PUCCINIA PAMMELII (Trel.) Arth. — Teleutospores from *Panicum virgatum* L. sown on *Euphorbia corollata* L.

13. PUCCINIA SUBNITENS Diet. — Teleutospores from *Distichlis spicata* (L.) Greene, sown on *Erysimum asperum* DC., *Sophia incisa* (Eng.) Gr., *Lepidium Virginicum* L. and *Bursa Bursa-pastoris* (L.) Britt.

14. PUCCINIA POCULIFORMIS (Jacq.) Wettst. — Teleutospores from *Agrostis alba* L. sown on *Berberis vulgaris* L.

15. PUCCINIA SORGHI Schw.— Teleutospores from *Zea Mays* L. sown on *Oxalis cymosa* Small.; aecidospores from *Oxalis cymosa,* sown on *Zea Mays;* and uredospores from *Zea Mays* sown on same host.

16. PUCCINIA POLYGONI-AMPHIBII Pers. — Teleutospores from *Polygonum emersum* (Michx.) Britt. sown on *Geranium maculatum* L.

17. PUCCINIA HELIANTHI Schw. — Teleutospores from *Helianthus grosse-serratus* Mart. sown on *H. grosse-serratus* Mart. and *H. annuus* L.

18. PUCCINIA LATERIPES B. & Br. — Teleutospores from *Ruellia ciliosa* Pursh, sown on *R. ciliosa* Pursh and *R. strepens* L.

19. PUCCINIA PRUNI-SPINOSAE Pers. — Aecidiospores from *Hepatica acutiloba* D C. sown on *Prunus serotina* Ehrh.

20. PUCCINIA XANTHII Schw. — Resting teleutospores from *Xanthium Canadense* Mill. sown on same host.

B. Species reported now for the first time.

1. PUCCINIA SILPHII Schw. — Resting teleutospores from *Silphium integrifolium* Michx. sown on same host.

2. PUCCINIA GRINDELIAE Pk. — Resting teleutospores from *Gutierrezia Sarothrae* (Pursh) B. & R. sown on same host.

3. PUCCINIA SOLIDAGINIS Pk. — Resting teleutospores from *Solidago trinervata* Greene, sown on *S. Canadensis* L.

4. PUCCINIA TRANSFORMANS E. & E. — Resting teleutospores from *Stenolobium Stans* (L.) Don. sown on same host.

5. PUCCINIA KUHNIAE Schw. — Teleutospores from *Kuhnia eupatorioides* L. sown on same host.

6. PUCCINIA CANALICULATA (Schw.) Lagerh. — Aecidiospores from *Xanthium Canadense* Mill. sown on *Cyperus esculentis* L.

7. PUCCINIA ELEOCHARIDIS Arth. — Teleutospores from *Eleocharis palustris* (L.) R. & S. sown on *Eupatorium perfoliatum* L.

8. PUCCINIA SUBSTERILIS E. & E. — Amphispores from *Stipa viridula* Trin. sown on same host.

9. PUCCINIA SEYMOURIANA Arth. — Teleutospores from *Spartina cynosuroides* Willd. sown on *Cephalanthus occidentalis* L.

10. UROMYCES ACUMINATUS Arth. — Teleutospores from *Spartina cynosuroides* Willd. sown on *Steironema ciliatum* (L.) Raf.

Purdue University, Lafayette, Ind.